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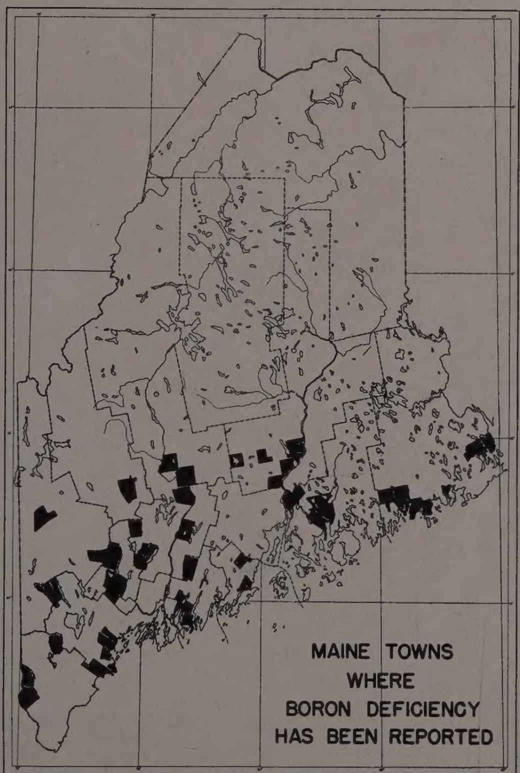
The Maine Agricultural Experiment Station
ORONO

BULLETIN 402 — AUGUST, 1940

Boron Deficiency Symptoms in Some Plants of the Cabbage Family



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BULLETIN 402

BORON DEFICIENCY SYMPTOMS IN SOME PLANTS OF THE CABBAGE FAMILY*

FREDERICK B. CHANDLER

INTRODUCTION

Water heart in rutabagas was observed in Maine by C. D. Woods (27) in 1914. The cause of the defect, however, was not known until 1933 when MacLeod and Howatt (17) showed that it was controlled by the application of borax to the soil. Since 1935 many investigators in various parts of the world have found that numerous crops develop abnormally in the absence of boron.

The work reported here was started at the Maine Agricultural Experiment Station in the fall of 1933, a year when many of the rutabagas grown in the state were affected with water heart. In 1936 the investigations were enlarged to include eleven members of the genus *Brassica* (part of the cabbage family). Up to this time only two plants of this genus, rutabaga and cauliflower, had shown boron deficiency in the field. All plants have been studied in the greenhouse under controlled conditions and some plants have been studied in the field. Part of the greenhouse experiments reported here were conducted at the University of Maryland.

The greenhouse experiments were conducted in sand cultures to which the nutrients[1] were added continuously. All plants were supplied with a small amount (0.05 or 0.1 ppm.) of boron for a period of at least 18 days. After this period plants were given a nutrient solution with a smaller quantity of boron or a nutrient solution without boron.

A brief explanation of some of the terms used in describing boron deficiency symptoms may be helpful. *Brown heart* is a name

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* The major part of this bulletin was part of a thesis submitted to the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[1] The nutrient solution for these experiments was of the same composition as that previously used by Johnston and Dore (14) in their studies of the boron requirements of tomatoes and was supplied by the continuous flow method of Shive and Stahl (25).

given to an area of dead cells in the roots of rutabagas and turnips and in the stem of kohlrabi. In the early stages of deficiency this appears watery and in very severe cases a cavity is developed. Severe cases are sometimes called "hollow heart." The words *cork, corky,* and *corky appearance* refer to a rough, light brown area on the surface of plant parts. In the majority of cases this is not true cork. *Cracks* are longitudinal splits in the petioles, stems, and roots of plants except in Chinese Cabbage where they are transverse. *Curling* is an abnormal bending downward of the mid-rib. *Dwarfing* is a reduction in size of plant parts usually without a reduction in the number of parts. *Rolling* is a marginal bending upward or downward of the leaf from the mid-rib. In *rugose* leaves the veins and veinlets are sunken and the spaces between them are elevated. *Swellings* are protuberances composed of much elongated thin-walled cells. *Wrinkled* veins follow a very irregular path in the plane of the leaf blade.

The few symptoms which are common to almost all plants of the cabbage family, grown without an adequate supply of boron, are described briefly. The leaves of plants developing after boron deficiency occurs are shorter and narrower than the leaves of healthy plants. However, the length-width ratio is seldom significantly changed. The entire plant is dwarfed and the apical meristem of diseased plants dies prematurely. Usually all other symptoms appear before this meristem is destroyed. The sequence of boron deficiency symptoms may vary, depending upon the age of the plant when boron becomes the limiting factor. The deficiency symptoms of eleven of the economic members of the cabbage family are presented below arranged alphabetically by the horticultural name of the plant.

BROCCOLI

Broccoli, *Brassica oleracea* L. var. *italica* Plenck,[2] horticultural variety Italian Green Sprouting, shows boron deficiency in the green house earlier than the other plants studied. In the field, however, it does not show symptoms as early as cauliflower or rutabaga. The first external symptom of boron deficiency is a

[2] L. H. Bailey, Manual of Cultivated Plants (New York: The Macmillan Co. 1938).

Fig. 1. Broccoli leaves showing curling and rolling.

Fig. 2. Broccoli grown with a very small amount (0.05 ppm) of boron for 22 days and then no boron. The older leaves of this plant have fallen off and the remaining leaves are curled and rolled.

curling and rolling of the leaves followed by a falling off of the older leaves, Figures 1 and 2. Soon, small swellings appear on the stem and under side of the petiole, which later have a corky appearance, Figure 3. About the same time longitudinal cracks

FIG. 3. Petioles and midrib of broccoli showing the development of swelling and cork. From left to right swelling just started, somewhat larger and transparent with a light green color, shallow crack with a corky surface, and swellings on the secondary veins.

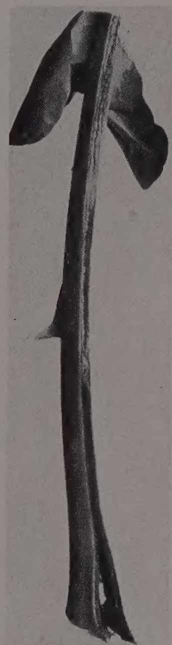

Fig. 4. Petiole from a broccoli plant showing boron deficiency as a split petiole.

Fig. 5. All of the buds on one of the clusters of the broccoli head on the left have fallen off and part of the buds on other clusters. The head on the right has brown buds scattered over it.

of various lengths appear on the petiole, most frequently on the under side, Figure 4. The leaves are very brittle. If the plant is not in bud or flower, the stem stops growing quickly, resulting in a flat top, and lateral shoots develop more abundantly than usual. If the plant is in bud, the individual buds turn brown and fall off, leaving an unmarketable head. Such heads are irregular in shape and of poor quality, Figure 5. When the plant is in blossom the seed pods fall before seeds are developed. In the field plants have been observed with curled leaves, cracked petioles, cork on the stem and petioles, and brown buds.

BRUSSELS SPROUTS

Brussels sprouts, *Brassica oleracea* L, var. *gemmifera* Zenker, horticultural variety Special Italian, does not show the symptoms

FIG. 6. Swellings on the stem of Brussels sprouts.

of boron deficiency as quickly as does broccoli nor do the symptoms progress as rapidly after they appear. The first external symptom is the appearance of swellings which later have a corky appearance. These may appear on the petioles or stem. The swellings which appear on the stem occur just above the axillary

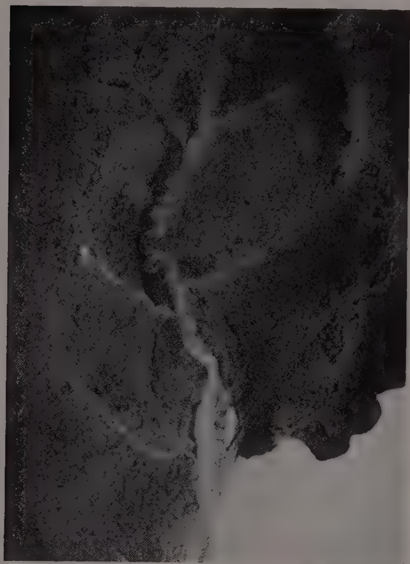

FIG. 7. Leaf showing wrinkled veins.

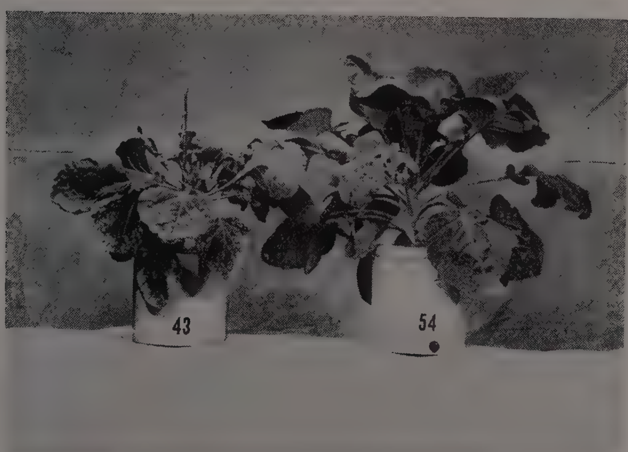

FIG. 8. The plant on the left did not receive an adequate quantity of boron and shows rugose, chlorotic leaves. The plant on the right is healthy.

FIG. 9. Brussels sprouts showing the premature death of the apical meristem.

bud and spread vertically and laterally, Figure 6. The veins of the leaves of plants which do not receive sufficient boron are wrinkled, Figure 7. The leaves at the base of affected plants fall off before the basal leaves of healthy plants. Chlorosis is very common, occurring first at the margin of the leaf and progressing toward the midrib, Figure 8. Later a red pigment develops on the under side of the leaf. The death of the tip of the plant is usually the last external symptom, Figure 9. When the deficiency occurs before the sprouts begin to develop, no sprouts are produced or they are very small. If the deficiency occurs after the sprouts have started to develop, the sprouts are smaller than usual and the outside leaves are distorted and curled outward, forming very loose sprouts, Figure 10.

FIG. 10. Brussels sprouts produce very loose sprouts when boron is not adequate.

CABBAGE

Cabbage, *Brassica oleracea* L. var. *capitata* L., horticultural varieties Early Jersey Wakefield and Mammoth Red Rock, shows externally the degree of boron deficiency and the age of the plant when boron became deficient better than any other of the members of this group. The leaves of plants which become deficient after the head has begun to develop droop and have a wilted appearance, yet feel very thick and stiff. On the other hand, if the head has not started to develop the leaves are curled, due to a more rapid growth of the top than of the bottom of the leaf. Some of the leaves may be broken by the strain resulting from the difference

FIG. 11. Plant, upper left, shows the wilted appearance of a plant receiving too little boron. Plant, upper right, has leaves broken by the mechanical stresses set up when boron is not supplied. Plant, lower left, produced no head. Plant, lower right, is healthy .

in growth rate, Figure 11. Such leaves are very brittle and break easily when touched. Like the preceding plants, cabbage, particularly the red cabbage, has swellings which later cork over. In cabbage these gradually develop up the petiole, on the under side, on to the midrib and occasionally are found on the secondary and tertiary veins, Figure 12. When the deficiency occurs before the head starts to form, no head is produced, Figure 13. However, if the head is fairly well developed when the deficiency occurs, abscission of the outside leaves of the head causes the head to appear yellow, Figure 14. Almost all of the midrib of the outer leaves of the head may have cork at the time of harvest, Figure 15. The stem of cabbage plants which have not been

FIG. 12. A red cabbage leaf which shows swellings on the under side of the petiole and midrib. The interior of the stem of the plant has brown spots especially near the top.

adequately supplied with boron have brown areas similar to those found in cauliflower suffering from this deficiency. Plants have been observed in the field with abscised outer leaves of the head and with brown areas in the stem.

Kimbrough (15) in reporting on the effect of sources of nitrogen found that nitrate of soda was superior to calcium nitrate for the growth of cabbage. The description and pictures suggest that

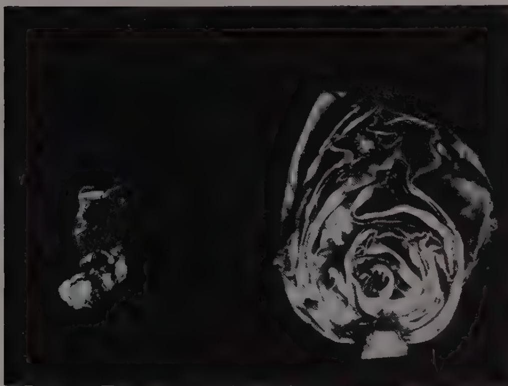

Fig. 13. Cabbage plants produce no head if deficiency occurs before head formation begins (left). However, if head formation has started a small loose head is produced (right).

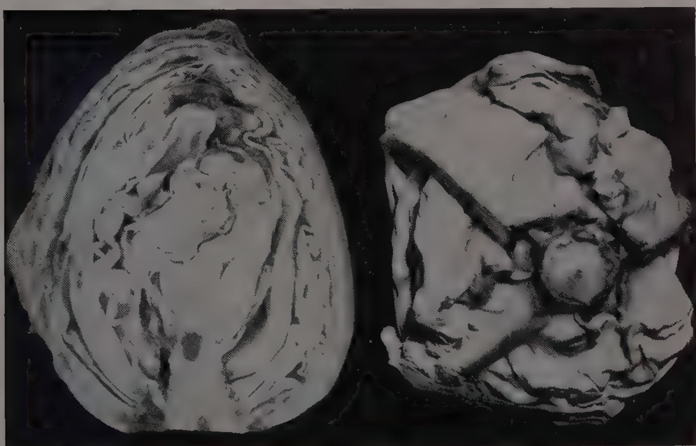

Fig. 14. When boron deficiency occurs after the head is formed abscission causes the leaves to separate from the stem. The picture on the left is of a plant gown in the greenhouse while that on the right is of a field-grown plant.

his cabbage plants were suffering from boron deficiency even when supplied with Chilean nitrate of soda.

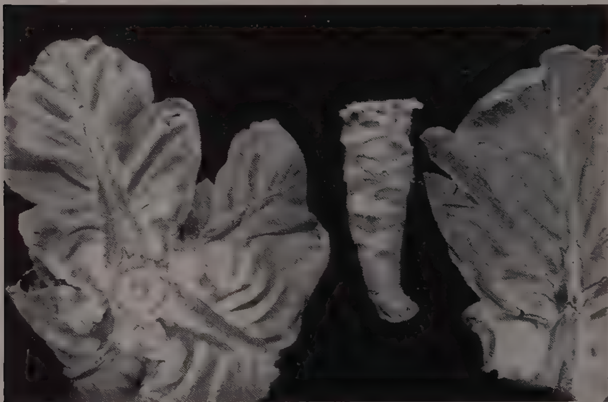

FIG. 15. The outer leaves of a cabbage head suffering from severe boron deficiency. Note the corky appearance of the midrib and veins.

CAULIFLOWER

Cauliflower, *Brassica oleracea,* L. var. *botrytis,* L., horticultural variety Super Snowball, several strains, becomes brown on the surface of the head when boron is deficient. This disease, called brown rot of cauliflower, has been known for twenty-five or thirty years and has caused serious damage to cauliflower, particularly in some sections of New York state. Chupp and Horsfall (4) published a description of the disease in 1933 and stated the disease was most severe in seasons with low rainfall during June and July. These investigators and others could not isolate any organism and Chupp and Horsfall thought the trouble might be related to waterheart in rutabaga. In 1935 Dearborn and Raleigh (5) prevented this disease, also called internal browning, by applying borax at the rate of 1.25 pounds in the row and 5 pounds broadcast per acre. The latter investigators with Thompson (6) published the results of greenhouse and field experiments a year

later showing the trouble was prevented with 6 pounds of borax per acre.

The first symptom of boron deficiency in cauliflower is a rolling of the leaves, usually downward. At this time the leaves are very brittle, breaking easily when touched and occasionally breaking without being touched, Figure 16. Later the younger leaves are very badly rolled and curled and the intermediate leaves may be rugose. In severe cases the young leaves have an enlarged midrib, with no leaf blade, Figure 17, and affected leaves frequently have cork on the midrib. Plants suffering from this deficiency are always dwarfed. When boron deficiency is not severe a head is developed which has watery or brown areas and the stems of such heads have transparent or brown areas, Figure 18. No head is produced on extremely deficient plants. Some workers have believed that boron deficient cauliflowers have hollow stems, but in a field experiment in 1937 no relation could be found between boron deficiency symptoms and hollow stems or between the amount of borax applied, up to 50 pounds per acre, and the number of plants with hollow stems. In plants showing boron deficiency the tissue around the cavity of a hollow stem is always watery or brown as is true also for broccoli. Hartman (11) working at Purdue University and Long Island observed hollow stems with one of his

Fig. 16. The plant on the left received boron for only 18 days. The leaves are curled, rolled and cracked and the head is very small and brown. The plant on the right was supplied with boron continually.

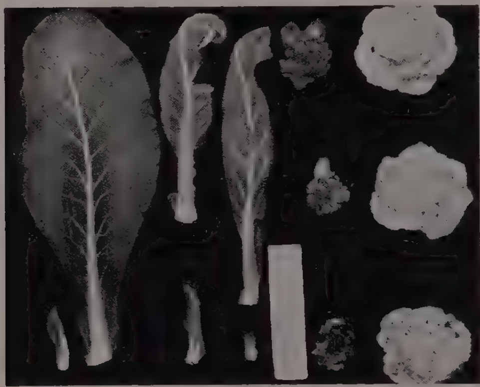

FIG. 17. The two leaves on the left are from healthy plants and the four in the center are from boron deficient plants. The heads on the right are from healthy plants while the others are from deficient plants.

boron treatments and stated, "This was the only case in this experiment, or in any others, where hollow stem was produced in the greenhouse without known boron deficiency." The author

FIG. 18. Field-grown plants with varying degrees of boron deficiency. The two heads on the right and part of the second one from the left are severely affected with boron deficiency. Note the watery and brown areas in the stem.

has observed all of the symptoms of boron deficiency in cauliflower under field conditions.

CHINESE CABBAGE

Chinese Cabbage, *Brassica pekinensis* Rupr., horticultural variety Chihli (Celery Cabbage), has curling and rolling of the leaves, particularly at the tips as a first symptom of boron deficiency. Later the deficient plants have rugose leaves much like the leaves of savoy cabbage, Figure 19. When the deficiency extends for a period of time, the midrib becomes cracked inside transversely and the

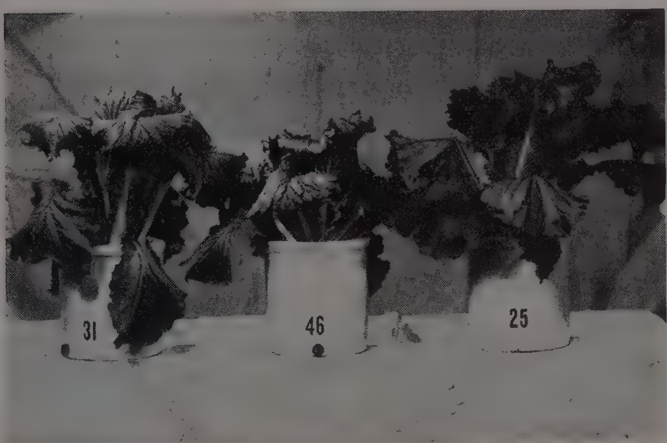

Fig. 19. The two Chinese cabbage plants on the left have curled rugose leaves due to boron deficiency. The plant on the right is healthy.

leaf becomes chlorotic, Figure 20. This is the only plant in the *Brassica* group which has transverse cracks and is unlike celery which has the cracks on the outside of the petiole (22). Deficient Chinese cabbage plants do not produce a marketable head as the top of the stem is killed early, Figure 21. No symptoms of boron deficiency in this plant have been observed in the field.

FIG. 20. The leaf on the left shows transverse cracking of Chinese cabbage due to insufficient boron. The leaf on the right is healthy.

FIG. 21. Without boron Chinese cabbage do not produce a marketable head. The heads on the left are from plants poorly supplied with boron, while those on the right are from healthy plants.

KALE

Kale, *Brassica oleracea* L. var. *acephala,* DC., horticultural variety Dwarf Blue Scotch, like Chinese cabbage develops fewer symptoms of boron deficiency with this element lacking than do

Fig. 22. The kale plant on the left received boron only during its early stage of growth. The one on the right received boron continually.

Fig. 23. Healthy kale leaves have a dark green color (left) while boron deficient leaves are chlorotic (right).

some of the slow growing plant. When boron is withheld from the nutrient solution, the leaves of kale are more curled and rolled than the leaves of deficient plants already described, Figure 22. Chlorosis is distributed over the entire leaf, Figure 23. The leaves of deficient plants are frequently rugose. Like other plants in this genus, brown areas appear inside the stem before the tip dies, Figure 24. The tip does not die until the internal breakdown has extended to the outer part of the stem, apparently cutting off the supply of nutrients from the root. Lateral shoots frequently develop below the dead tip.

FIG. 24. Longitudinal section through the stem of kale plants. The stem in the top row left is from a healthy plant. The other stems show varying amounts of boron deficiency.

KOHLRABI

Kohlrabi, *Brassica oleracea* L. var. *caulorapa* Pasq., horticultural variety White Vienna, grows more erect when boron is limited than when boron is adequately supplied, Figure 25. In this respect

Fig. 25. The two kohlrabi plants on the left show boron deficiency. The one on the right is healthy.

kohlrabi is unlike other members of the genus *Brassica*. The curling and rugosity of the leaves is not quite as noticeable and the swellings on the stems in deficient plants is less common than in other members of the genus *Brassica*. If the plant is deprived of boron before the edible part of the stem starts to develop, little or

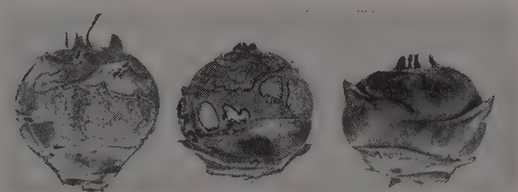

Fig. 26. The outer surface of kohlrabi becomes rough when boron is insufficient (two on left).

no development takes place. However, when boron is removed from the plant after the edible part (tuberous stem) has begun to enlarge, further development is slightly retarded and the surface becomes more or less covered with cork, Figure 26. Such tuberous stems are often abnormal in shape and develop watery or brown areas in the interior and in some cases become hollow, Figure 27. These symptoms have been observed only in the greenhouse.

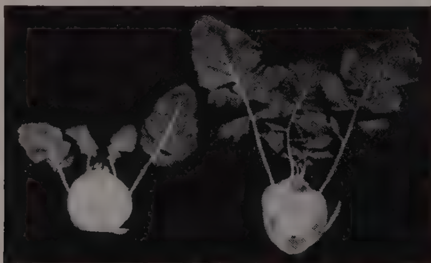

FIG. 27. The inside of kohlrabi stems become watery, brown or hollow when the plants are deprived of boron.

WHITE MUSTARD

White Mustard, *Brassica alba,* Rabenn, horticultural variety White London, supplied with boron for 15 days has no deficiency symptoms when grown for greens. However, plants grown for seed fail to flower when boron deficiency occurs before flower formation and fail to fruit when the deficiency occurs just after flower formation. Deficient plants are dwarfed, have curled leaves which frequently roll down, and show rugosity, Figure 28. Deficient plants have fewer seed stalks and the ones produced are short with malformed blossoms and leaves. The wild black mustard has the same symptoms of boron deficiency.

Fig. 28. The two white mustard plants on the left did not receive enough boron. The one on the right is healthy.

RAPE

Rape, *Brassica Napus,* L., has almost the same symptoms of boron deficiency as kale. The plant is dwarfed, has rugose, chlorotic, rolled leaves which have cracked petioles. The stem usually has brown dead areas.

RUTABAGA

Brown heart in rutabaga, *Brassica napobrassica,* Mill., horticultural variety American Purple Top, has been observed for twenty-five years or more. In 1915 Woods (27) described the disease and presented the results of the previous season's work which showed that the condition was not caused by an organism and could be partially controlled by the use of manure. Hurst (12) came to similar conclusion in 1930. In 1934 MacLeod and Howatt (17) found that brown heart could be controlled by apply-

ing 10 pounds of borax per acre in the row. Since 1934 investigators all over the world have studied browning of rutabaga and the amount of boron necessary to control it.

In the summer of 1934 field experiments were conducted in eastern Maine, a section of the state commonly producing rutabagas commercially. Since that time many experiments have been conducted with rutabaga in the field and in the greenhouse. The field experiments have shown that 5 and 8 pound applications were not sufficient, but the 10 pound applications prevented brown heart in all of the field trials in the rutabaga section. In one experiment in 1937 in which the borax applications varied from 5 to 50 pounds per acre, the highest application produced much better rutabagas than the lower ones but none of the applications produced rutabagas entirely free from brown heart. Many of the rutabagas grown in this field were affected with cabbage root maggot or club root or both. Cauliflower grown in the same field showed only a small percentage of plants with boron deficiency symptoms. Probably a small part of this difference was due to seasonal effect as the cauliflower was transplanted into wet soil and grew mostly during a wet period. Later, when the rutabaga was planted, there was very little rain and a dry growing period. Other investigators have found a seasonal effect for rutabaga (3, 10, and 27), for apples (23); for sugar beets (1, 16, and 18), for potatoes (20), and for crops in general (7 and 8).

In fields where boron is present in quantities just adequate to produce marketable rutabagas under normal growing conditions, an infestation of the cabbage root maggot or of club root will cause boron deficiency symptoms to develop. Therefore, the control of the insect and the disease is of great importance in fields which have just enough boron for plant growth. When the effects of a dry season, insects, and diseases are accumulative, the recommended amount of borax, ten pounds per acre in the row, may not be sufficient to prevent the development of some deficiency. However it is not considered advisable to increase the amount as this would be detrimental in normal seasons.

When rutabagas are not adequately supplied with boron in either greenhouse or field, the plants are dwarfed and have curled leaves which are rugose, Figure 29. The older leaves are more brittle and more horizontal in plants not supplied with boron than are the leaves in healthy plants. In severe cases of deficiency the

leaf margins are chlorotic (17), a reddish purple pigment develops on the under side of the leaves and they fall prematurely (13), Figure 30.

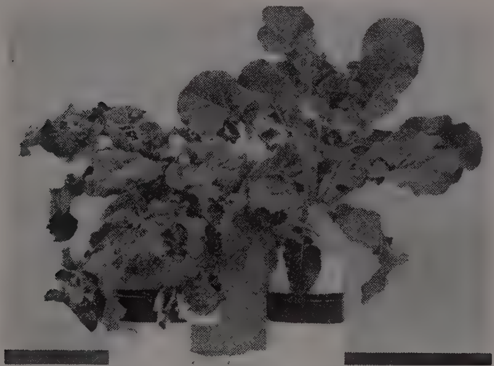

FIG. 29. The rutabaga plant on the left has boron deficiency. The one on the right is healthy.

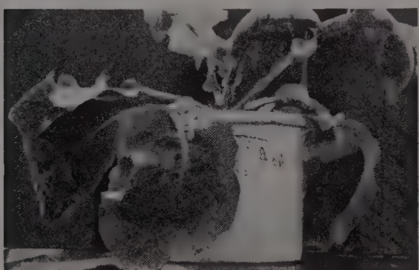

FIG. 30. A rutabaga plant severely affected with boron deficiency. This plant had chlorotic leaf margins with pigment on the under side of the leaves.

In 1935 the author with others (2) stated that rutabagas affected with boron deficiency often had rough skins and the roots were cracked, Figure 31. However, it has been the opinion of some investigators (9, 19, 21, and 26) that there were no external

symptoms. The severity of the deficiency varies the amount and the type of the injury inside the storage root. In some cases the injured tissue has a watery appearance, in others brown spots occur, and in most severe cases a cavity develops in the storage root, Figure 32. The brown heart in storage roots has various

FIG. 31. This picture shows the top and side views of each of six rutabaga roots. Top row healthy, bottom two rows have brown heart.

designs. The affected areas may be small and scattered or they may have a tendency to be grouped or they may be in rings, Figure 33. Brenchley (1), Donaldson (9), and O'Brien and Dennis (7) have stated that brown heart did not extend to the top of the rutabaga root, and Riggs, Askew and Chittenden (24) have stated that brown heart did not extend to the bottom. However, the author has observed rutabagas in the field which were affected at the top and down to the bottom of the storage root. In the greenhouse boron deficient rutabagas have smaller storage roots than healthy ones, but in the field there is little or no difference in size.

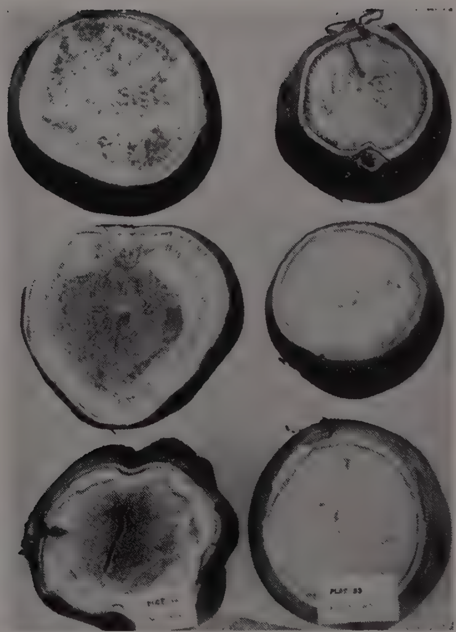

Fig. 32. Rutabagas with no borax, and with 5 pounds per acre. Without borax the roots were watery, brown or hollow hearted (left). With 5 pounds of borax per acre some of the roots were normal and some had brown heart (right).

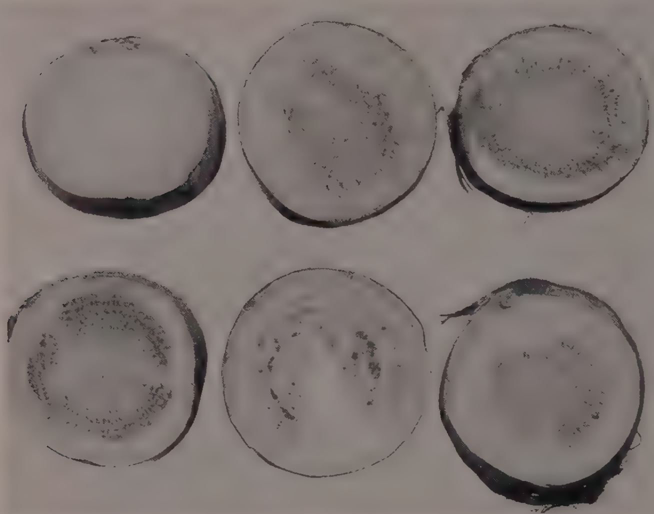

FIG. 33. The rutabaga in the top left hand corner is healthy. The others show varying degrees of brown heart.

TURNIP

In turnip, *Brassica Rapa* L., horticultural variety Purple Top White Globe, boron deficiency symptoms are almost the same as those for rutabagas, Figure 34.

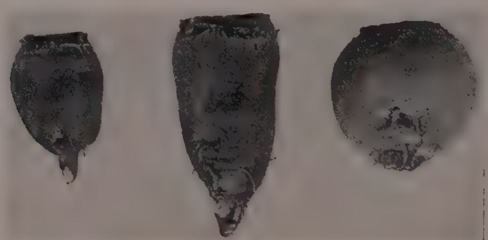

FIG. 34. Turnips have a rough surface when grown without boron (two on left), while healthy roots have a smooth surface (right).

OTHER PLANTS WHICH FREQUENTLY HAVE BORON DEFICIENCY

The effect of an inadequate supply of boron is known for a large number of crops. The following is a list of some of the crops which may be grown in Maine, together with a brief description of a symptom or symptoms of boron deficiency of each type of plant.

Alfalfa	Dwarfed plants with yellow leaves.
Apples	"Internal cork" or "corky core" of the fruit.
Beets	"Black heart" or "dry rot" of the edible root.
Carrots	Death of the growing tip.
Celery	"Cracked stem," a transverse cracking of the petioles.
Corn	Yellow streaks in the leaves and death of the growing point.
Lettuce	Curled leaves and dead center in the head.
Potatoes	Rolling of the leaves resembling "leaf roll."
Spinach	Dwarfed plants with some black rot.
Strawberries	Irregular leaves and small poorly shaped berries.
Sunflowers	Curling and yellowing at the base of the top leaves and death of the growing point.
Tomatoes	Small spots resembling blossom end rot but usually not occurring at the blossom end.

AREA OF MAINE IN WHICH BORON DEFICIENCY HAS BEEN REPORTED

The information used in this section has been obtained from County Agents, Crop Specialists, reports of growers, correspondence, and observations in the field. In general the area showing deficiency is the entire cultivated area in the southern part of the state, Figure 35 and Table 1. Boron deficiency has been observed on many farms in the market garden section around Cape Elizabeth and in the turnip sections near Perry. These areas have been settled longer than the cultivated area in the eastern part of Aroostook County in which no boron deficiency symptoms have been observed. The towns where deficiency has been reported were all

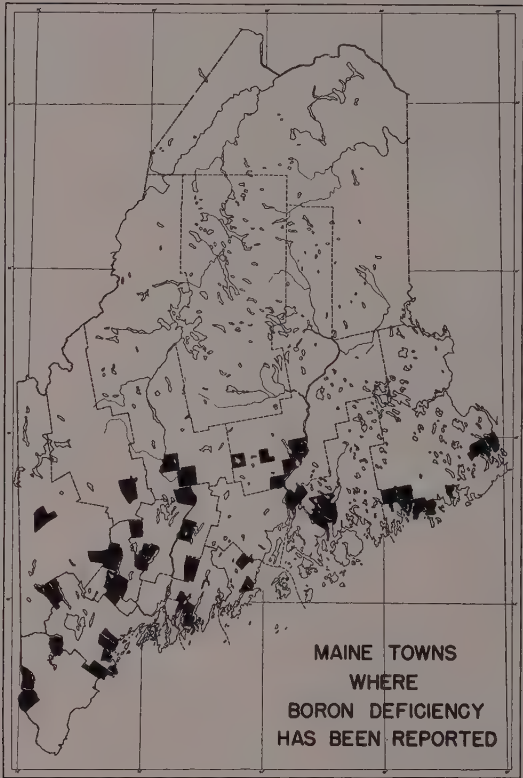

FIG. 35. The black areas are towns in which boron deficiency has been reported for one crop or another.

settled before 1800 except those in Penobscot County. The largest number of reports of deficiency is from Scarboro and Cape Elizabeth, and these towns were two of the earliest to be settled in Maine, 1630. From the small amount of information available for Maine, there seems to be a high association between boron deficiency and the date of settlement of the town and little or no association between boron deficiency and the parent soil material or the natural boron content of the soils type.

TABLE 1

Counties and towns where boron deficiency has been reported with the crop or crops on which the deficiency was observed

County	Town	Date		Crop or crops on which boron deficiency has been reported
		Settled	Incorp.	
Androscoggin	Auburn	1786	1842	apples, turnip
	Buckfield		1793	cauliflower, turnip
	Lewiston	1770	1795	rutabagas, turnip
	Turner	1690	1786	turnip
Cumberland	Bridgton	1770	1794	cauliflower, strawberries
	Cape Elizabeth	1630	1765	cauliflower, celery, rutbagas
	Cumberland Center	1750	1821	cauliflower, rutabagas
	Falmouth	1632	1718	cauliflower, rutabagas
	Portland	1633	1786	beets, cauliflower, rutabagas, spinach, tomatoes
	Scarboro	1630	1658	cauliflower, rutabagas
Franklin	Farmington	1776	1794	turnip
Hancock	Bucksport	1762	1792	mangold beets
	Ellsworth	1763	1800	rutabagas
	Surry	1785	1803	rutabagas
Kennebec	Kents Hill	1760	1791	turnip
	Monmouth	1775	1792	cabbage, cauliflower, rutabagas
	Vassalboro	1760	1771	cauliflower
Knox	Hope	1782	1804	turnip
	Rockland	1719	1848	cauliflower
	Thomaston	1719	1777	cabbage, turnip
Oxford	N. Newry	1781	1895	beets, cauliflower, rutabagas, turnip
Lincoln	Boothbay	1630	1764	turnip
	Edgecomb	1774	1774	vegetables
	Whitefield	1770	1809	vegetables
	Wiscasset	1663	1802	vegetables
Penobscot	Bangor	1769	1791	cabbage
	Hampden Highlands		1794	turnip
	Levant	1800	1813	corn, tomatoes, turnip
	Lincoln Center	1825	1829	rutabagas
	Newport	1808	1814	celery, lettuce, turnip
	Orono	1774	1806	cabbage, cauliflower, rutabagas
	Stillwater	1774	1806	cauliflower, rutabagas
Somerset	Fairfield	1774	1788	apples, kohlrabi, turnip
	Madison		1804	turnip
	Skowhegan	1770	1823	turnip
Washington	Addison	1779	1797	rutabagas, turnip
	Cherryfield	1757	1816	rutabagas, turnip
	Columbia		1796	rutabagas, turnip
	Dennysville	1786	1818	rutabagas, turnip
	Harrington	1765	1797	turnip
	Jonesport		1832	rutabagas, turnip
	Lubec	1780	1798	rutabagas
	Machias	1763	1770	rutabagas, turnip
	Pembroke	1770	1832	rutabagas, turnip
	Perry		1818	rutabagas, turnip
York	Acton	1772	1830	vegetables
	East Lebanon	1733	1767	cauliflower, rutabagas
	Limington		1792	vegetables
	Lebanon	1733	1767	vegetables

METHODS OF CONTROL

Boron deficiency is easily and inexpensively controlled but care must be exercised in the amount of boron used as too large quantities are toxic to plants. Any compound containing boron may be used but borax is most frequently employed as it is cheap and available in almost every community. It may be purchased from some fertilizer companies in quantities larger than the one pound grocery package. Borax may be applied in the following four ways: in the fertilizer in the row, in the fertilizer broadcast, as a side dressing, and as a spray. Table 2 gives the amounts of borax to be mixed with the fertilizer for row applications. For broadcast applications twice as much borax should be used. A very

TABLE 2

Length of row and amount of fertilizer and borax to be mixed for row application to prevent boron deficiency

Length of row	Fertilizer	Borax		
Feet	Pounds	Grams	Ounces	Volume*
50	2.1	13.0	0.5	2 tablespoons
100	4.2	26.0	1.0	3 tablespoons
150	6.3	39.0	1.5	5 tablespoons
200	8.4	52.0	2.0	7 tablespoons
400	16.8	104.1	3.5	1 cup
700	29.4	182.1	6.5	1.5 cups
1,000	42.0	260.2	9.25	2 cups

* Level full.

thorough mixing of the borax and fertilizer is necessary in order to supply the borax to the plants uniformly. For some crops it may be desirable to use larger amounts of fertilizer than is indicated in Table 2, but the amount of borax should not be increased for any crop. The fertilizer and borax in row applications should be covered with soil before the seed is planted or before plants are set and they should be cultivated in when broadcast applications are made. If the plants are up before the borax is applied, the amounts presented in Table 2 may be mixed with sand and the mixture applied as a side dressing. The borax also may be dissolved in water and applied with a watering can along the row or it may be applied as a spray with insecticides or fungicides in con-

nection with insect or disease control. Boron may be added also to corrosive sublimate used to control club root and root maggots. When it is added to corrosive sublimate, it must be added as boric acid, Table 3, as borax causes a precipitate to be formed in mercuric solutions. In setting out plants, a half cup of the corrosive

TABLE 3

The quantity of boric acid to be added to corrosive sublimate to control boron deficiency when one-half cup of sublimate solution is used per plant

Gallon of corrosive sublimate	Boric Acid		
	Grams	Ounces	Volume*
8	19.1	¾	2 tablespoons
10	23.9	1	3 tablespoons
16	38.2	1¼	5 tablespoons
20	47.8	1¾	6 tablespoons
24	57.3	2	7 tablespoons
30	71.7	2½	9 tablespoons

* Level full.

sublimate and boric acid solution should be used per plant and should be poured into the hole prepared to receive the plant.

SUMMARY

A deficiency of boron causes plants to be dwarfed and to have curled, rolled leaves often with chlorotic margins. The part of the plant which is grown for the market is most severely affected in size and quality. Boron deficiency has been observed in a large number of towns in southern and eastern Maine. Boron deficiency may be corrected by the use of ten pounds per acre of borax applied in the row for row crops. Borax may be applied with the fertilizer, as a side dressing, or it may be applied in solution as a spray. In setting out plants, boric acid solutions may be used, the solution being poured into the holes prepared to receive the plants.

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